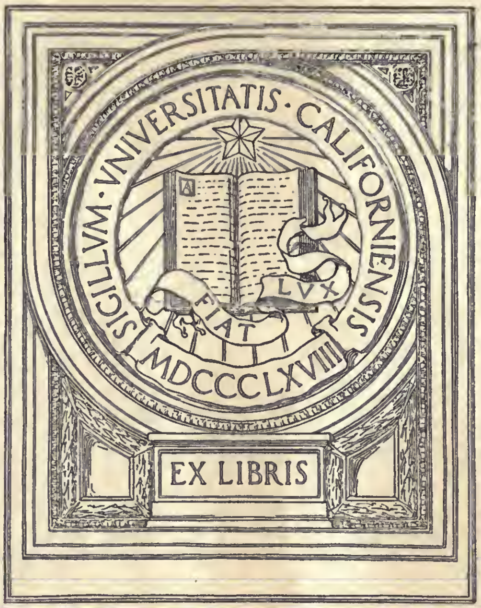

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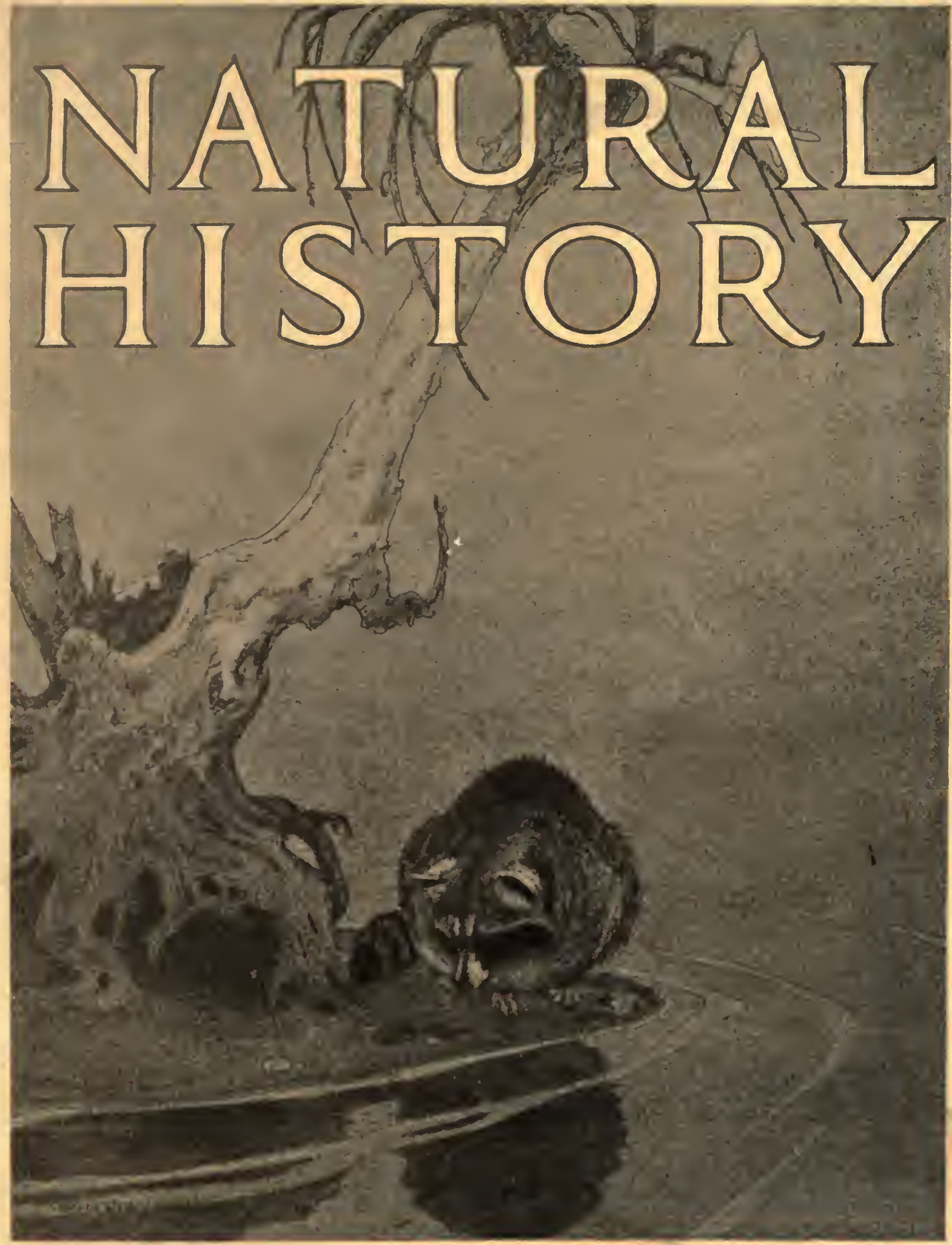

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THE JOURNAL OF THE AMERICAN MUSEUM

DEVOTED TO NATURAL HISTORY,
EXPLORATION, AND THE DEVELOPMENT OF PUBLIC EDUCATION
THROUGH THE MUSEUM

Lumholtz, Carl.
(Title : All 2 p. [illegible])

MAY—JUNE, 1921
[Published August]
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Published bimonthly, by the American Museum of Natural History, New York, N. Y. Subscription price $3.00 a year; foreign $3.50.

Subscriptions should be addressed to Henry P. Davison, Treasurer, American Museum of Natural History, 77th St. and Central Park West, New York City.

NATURAL HISTORY *is sent to all members of the American Museum as one of the privileges of membership.*

Entered as second-class matter April 3, 1919, at the Post Office at New York, New York, under the Act of August 24, 1912.

Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on July 15, 1918.

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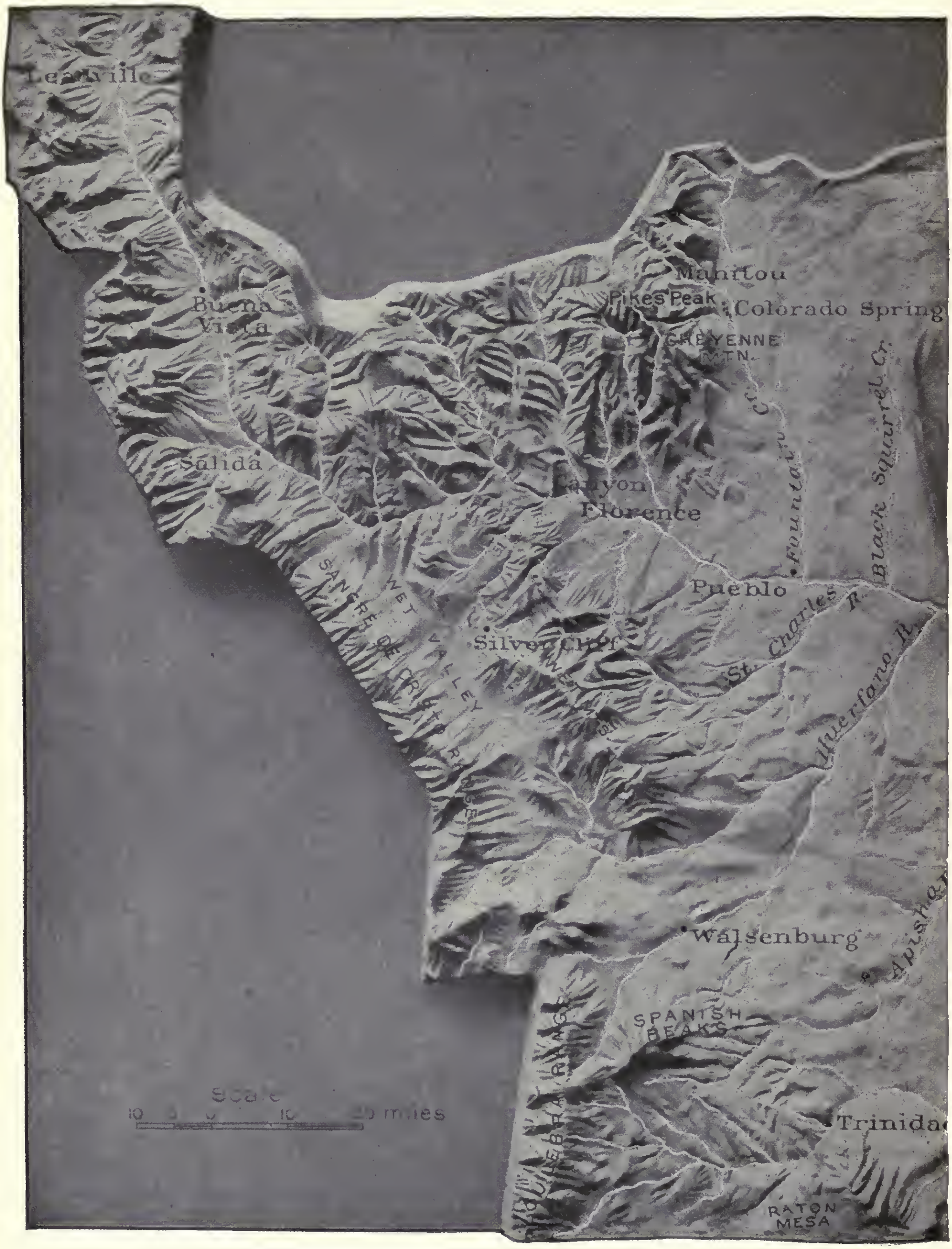

DRAINAGE BASIN OF THE ARKANSAS RIVER IN COLORADO

Pueblo and the region about it suffered most through the recent devastating floods, which left in their train death and destitution and spread terror even to regions beyond the reach of their menace

FLOODS IN THE PUEBLO DISTRICT.

BY

CHESTER A. REEDS*

THE recent disastrous floods at Pueblo and other Colorado towns in the Arkansas River valley have attracted nation-wide attention. The floods on the Platte River at Denver, Colorado, although less severe, have also damaged property and caused loss of life. These river floods have arisen from torrential rains and cloud-bursts in the headwaters of the Arkansas and Platte rivers. According to the reports of the United States Weather Bureau, the amount of precipitation in inches at Pueblo and Denver was as follows:

	Pueblo		*Denver*	
June 2, 1921	.12	inches	.02	inches
" 3, 1921	1.80	"	.08	"
" 4, 1921	2.92	"	2.04	"
" 6, 1921	.08	"	.06	"
Total	4.92	"	2.20	"

The newspaper accounts state that rain fell in this district on June 5 but the Weather Bureau reports the Pueblo record for that date missing; Denver, .42 inches. The annual precipitation for Pueblo and Denver is slightly under 15 inches. It is thus remarkable and unusual for one third of the annual precipitation to fall at Pueblo in the four days mentioned above. On May 31, 1894, Pueblo was swept by a flood similar to that of June 4, 1921.

The question thus naturally arises what peculiar geographical position has Pueblo that the city is subject to sporadic floods of such violent character as those reported in the daily press for the first week of June?

Pueblo and Denver are cities on the western margin of the Great Plains. These plains form a high plateau about 5000 feet above sea level and extend in a north-south direction from the Mexican border well into Canada. They are several hundred miles in width and slope gently to the east. Bordering the Great Plains on the west is the Rocky Mountain tract, which rises abruptly to an average elevation of 10,000 feet. Some of the mountain peaks rise higher, to 12,000 and 14,000 feet above sea level. Pueblo is situated at the confluence of Fountain Creek and the Arkansas River about ten miles east of the main Rocky Mountain front. Just west of Pueblo, however, the Great Plains embay the Rocky Mountain tract for an additional twenty miles so that a huge crescent-shaped amphitheater with a radius of about thirty miles centering at Pueblo lies to the west of the city. It was in this huge receptacle that the greater portion of the 4.92 inches of rain fell during the first week of June and converged upon the city.

Fountain Creek, which enters the valley of the Arkansas River at Pueblo through a narrow defile from the north, is primarily a Great Plains stream about sixty miles long. It drains the Rocky Mountain front about Pikes Peak, Colorado Springs, Manitou, and about twenty miles to the north of those places. Following heavy rains in the mountains at and above Pikes Peak, it becomes a raging torrent throughout its entire course. Most of the water which flooded Pueblo in 1894 came down this stream.

The Arkansas River, which enters Pueblo from the west across the floor and through the mid-portal of the Pueblo amphitheater, rises in the high Rocky Mountain tract about Leadville, Colorado, some 150 miles to the northwest of Pueblo. Many lateral tributaries are received by the river on its way to the Great Plains. The area drained is more than 4000 square miles in extent and is rudely triangular in shape with a 75-mile front facing Pueblo. The normal rainfall in the mountains is 20 inches while that on the Great Plains is less than 15 inches annually. During the three months of January, February, and March, the precipitation west of Pikes Peak averages 5.1 inches as contrasted with 1.4 inches at Pueblo. The normal annual snowfall in the mountains and on the plains about Pueblo and Denver is 40 inches, normal sunshine 60 per cent., normal temperature 50°, maximum 85°, minimum 15°. Had the precipitation during the first week in June been as heavy in the mountainous sections drained by the Arkansas River as in the Pueblo amphitheatre, the floods would have been far more disastrous than they were. Normally there is a large volume of water in the river passing Pueblo.

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*Associate Curator of Invertebrate Palæontology, American Museum

Pueblo, a city of 42,908 inhabitants according to the 1920 census, is situated in the valley of the Arkansas River at an elevation of 4675 to 4750 feet above sea level. The normal flood plain of the river, which has been narrowed during the growth of the city, was originally about one half mile wide and divides the city into north and south sections. Except for a narrow strip along the river bank the south section is built on an old alluvial terrace more than fifty feet above the river. Most of the north section is lower, with an average elevation of 4700 feet above sea level. A narrow insular remnant of the old alluvial terrace, which parallels the west bank of Fountain Creek at the confluence forms a bit of higher ground. The northern limits of the city extend into the uplands facing the river some two miles distant. Fountain Creek divides this section into two parts, with the main portion west of this stream and the Grove section to the east.

The transporting power of a large river in flood time is most surprising. It varies as the sixth power of the velocity. Thus if the velocity of running water is doubled, it increases its transporting power sixty-four fold. Swift streams, therefore, have enormously greater power of transportation than sluggish ones. The Arkansas at Pueblo in normal times has considerable water and a strong current, for bridges are necessary, but during flood its velocity and consequently its power may be increased enormously. The chief elements upon which the velocity of a stream depends are its gradient, its volume, and its load of sediment. The steeper the gradient, the greater the volume, and the less the load, the greater the velocity. The average grade of the Arkansas River from Canyon City at the mouth of the Royal Gorge across the floor of the amphitheater to Pueblo is 15 feet to the mile, from Pueblo to La Junta, 8 feet, and from La Junta to the Kansas line, 7.3 feet. The area of the Pueblo amphitheater, with a radius of thirty miles, is 1413 square miles. The recorded rainfall over this surface for the first week in June was 4.92 inches and with one day's record missing, the total may have been 6 inches. Imagine half a foot of water 1413 square miles in area on a grade of not less than 15 feet to the mile, augmented with a very large but unknown amount arising from a mountainous tract more than 4000 square miles in area, pouring through the small end of a huge funnel at Pueblo. It is true a portion of this rainfall may have sunk into the ground and a part evaporated, but it is assumed that far more than one third of it ran off, for it fell, for the most part, on impervious shale rock and during a few days.

It is not surprising, therefore, that whole trains standing in the railroad yards were dashed from their tracks and that bridges were carried away by the onrushing wall of water, which rose up to the level of second-story windows and continued for days. The load of sand, gravel, and mud, besides wreckage of every description, must have been enormous.

Where mountain streams debouch upon a plain, they drop a considerable portion of their load, particularly the large boulders and pebbles. This is due primarily to an abrupt change in gradient, which affects the velocity and consequently the transporting power of the stream. Where the declivities are steep and the streams short, alluvial deposits arise with cone-shaped outline, the base resting on the plain and the top leaning against the mountain. In the next step where youthful river courses are defined the sediments are spread fanwise over the plain at the foot of the mountains. In a later stage of development where the various streams have had time enough to work headward far back into the mountains, to cut deep cañons and to unite, forming the head waters of a large river such as the Arkansas, the change in stream gradient from mountains to plains is not so abrupt as in the earlier stages and fine deposits are strewn for hundreds of miles along the river course.

The present Arkansas River and its tributaries flow in deep and narrow cañons in the mountains, but in crossing the Great Plains their valleys are wide and average about two hundred feet below the surrounding higher lands. Between Pueblo and the mountains the Arkansas valley is bordered in places by cliffs of moderate height. but to the east the side slopes are very gentle.

Extensive deposits of conglomerates, sand, sandstone, gravel, and clay, known as the Monument Creek formation, appear on the high divide between the Platte and Arkansas drainage basins from the foot of the Rocky Mountains eastward. There are two members, a lower one of sand and clays and an upper one of conglomerate and sandstone. They cap numerous buttes and plateaus. These sediments represent fan-shaped deposits of the early Tertiary. Fossil bones of *Titanotherium*, found in the upper member, indicate Oligocene age.

Deposits of loose sand and coarse gravel about two hundred feet thick cover wide areas of the high plains adjoining the Arkansas valley in eastern Colorado and extend westward to the vicinity of Fountain Creek. They have been named the Nussbaum formation and are supposed to be of Pliocene age. Locally the beds consist of loose sandstones or very sandy limestones with carbonate of lime acting as a cement. These beds are of alluvial origin, having been spread where they lie by the flowing water of streams.

Along the Arkansas River below Pueblo appear large areas of alluvium. The thickness of this deposit is from fifty to sixty feet in the central portion of the valley and has a width in the bottom lands from three fourths of a mile to a mile. It consists of fine sands and loam laid down by the river at various stages. During floods coarser material is added, particularly on the lower flats. Similar alluvial deposits constitute the bottom lands along Fountain Creek. Higher terrace levels appear in places along these streams, capped by sand and gravel. The higher deposits represent early, and the lower ones, the present or late Quaternary deposition.

Thus it may be stated in conclusion that, whereas great floods have occurred sporadically at Pueblo since the founding of the city and oftentimes during late geologic periods, they are bound to occur again. The causes are natural and cannot be changed. If the river's course is kept free from unnecessary obstructions and as wide as possible, the danger is not apt to be so great. With city parks along the river banks and strong levees behind them the remainder of the city occupying the low ground may be kept free from floods.